8. *A more technical discussion of formats, resolution, pixels, lenses, and field of view*

A basic familiarity with camera terminology is probably adequate for most school administrators who plan to go out on bid for a CCTV system. However, for the benefit of those who might be responsible for choosing or upgrading camera equipment, the following discussion presents these technical specifications in more depth.

Formats. Camera format relates to the size of the camera imaging device. Most solid-state cameras used in security applications today are 1/2-inch or 1/3-inch format. There are some 2/3-inch cameras still in use, and some 1/4-inch format cameras are beginning to appear on the market. The trend has been to make camera formats smaller as picture element densities have increased, giving the manufacturer more imaging devices per production run, reducing costs, and allowing for smaller cameras.

Resolution. Resolution is the ability to resolve or see small details in an image. Resolution for CCTV cameras (as well as for TV monitors and recorders) is usually specified in terms of horizontal lines of resolution. Horizontal lines of resolution relates to the number of independently resolvable elements (small details) in three-fourths of the picture width. CCTV cameras range from 200 to more than 1,000 lines of horizontal resolution. Higher resolution cameras generally cost more than lower resolution cameras. For a typical color security camera system (system includes camera, cabling, recorder, and TV monitor) that uses a standard National Television Systems Committee (NTSC) color video signal format, 300 to 400 lines of horizontal resolution are common. Black-and-white systems for tighter security applications typically range from 500 to 700 lines of resolution. Cameras with more than 800 lines of resolution are commonly used in broadcast TV, medical, or industrial applications.

Pixels. Active picture elements, sometimes referred to as pixels, is a term used specifically with cameras and is directly related to horizontal lines of resolution. Active picture elements are the actual number of light-sensitive elements that are within the camera imaging device. Active picture elements are expressed with a horizontal number (the number of elements horizontally across the imager device) and a vertical number (the number of elements vertically on the imager). A camera specified with 768H by 494V picture elements has 494 rows of picture elements vertically, with each row having 768 elements horizontally. For black-and-white cameras, horizontal lines of resolution relate to picture elements by a three-fourths factor (by definition of horizontal lines of resolution) so a black-and-white camera with 768 active picture elements will have 576 horizontal lines of resolution. This would hold true for color cameras as well, except that the NTSC format limits signal bandwidth which reduces resolution.

Lines of resolution, camera format, and lens focal length (discussed later) are the camera-specific part of what determines if a camera scene will be useful for a particular application. Other items to consider include lighting, shadowing, camera aiming, and camera sensitivity. Before selecting a camera and lens combination for an application, one must determine what is desired to be seen in the image. Just being able to see a person in a specific area, such as a parking lot, will require one set of minimum criteria for camera and lens selection. Being able to identify a person by facial features (if the person faces the camera) will require a different set

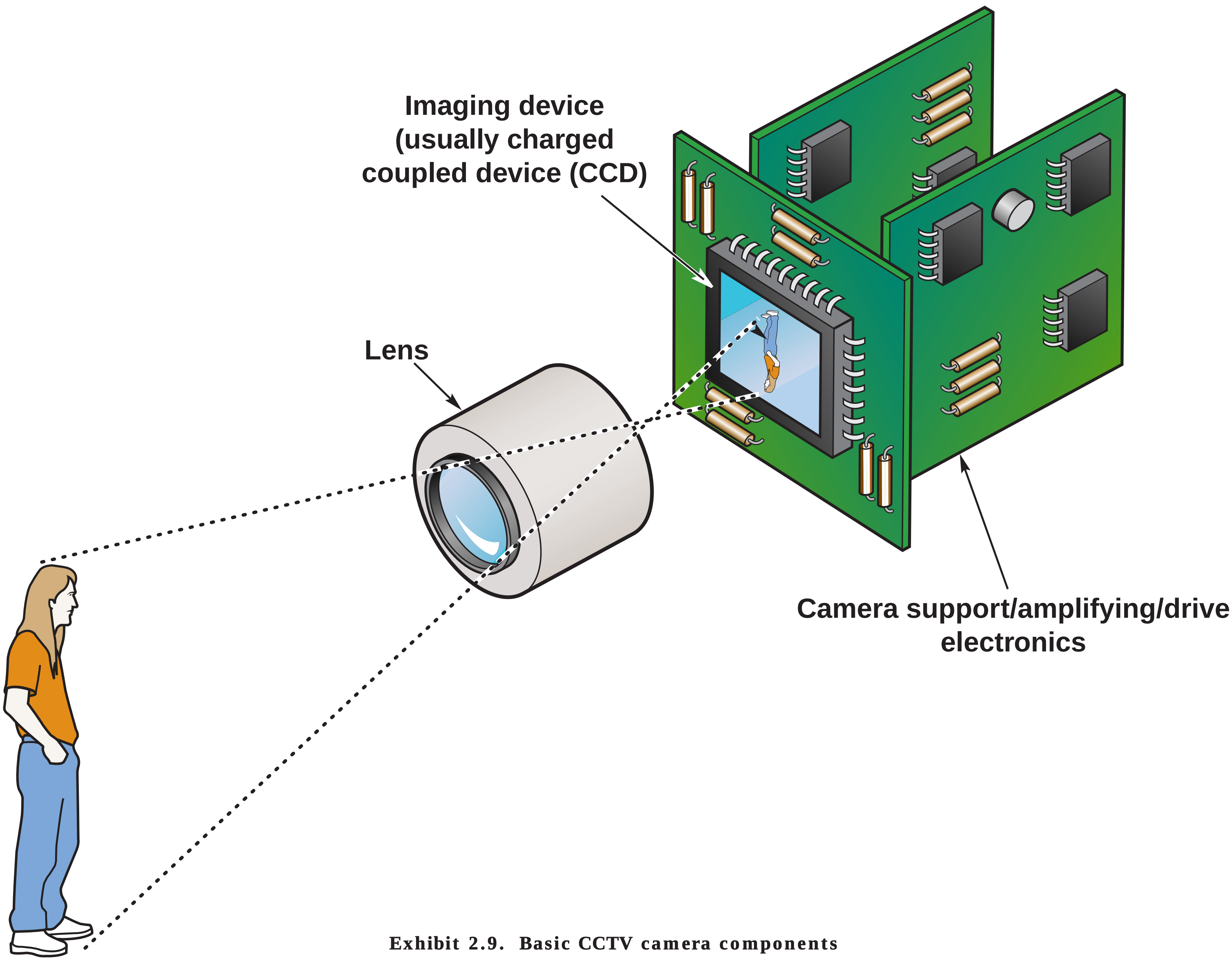

Exhibit 2.9. Basic CCTV camera components

of criteria. For identification purposes, a person must be much larger in a scene than for the purpose of just determining if a human is present.

Because a camera scene is observed on the TV monitor, the entire CCTV system resolution must be considered. This includes the camera and lens combination, the camera signal transmission equipment (such as coaxial cable and amplifiers), the TV monitor, and the recorder. All components of the system must have adequate resolution for the application desired.

For observation of a camera scene to determine only if a human is in the scene (or to be able to distinguish between a person and an animal), a minimum criteria of 6 horizontal TV lines across a 1-foot-wide object within the scene is used. (In terms of active picture elements, this means that a 1-foot-wide object would cover 8 horizontal active picture elements for each row of picture elements for the height of the object on the camera imager.) For identification of a person by facial features, 16 horizontal lines (21 pixels) of resolution subtending a 1-foot-wide object is needed.

The lens focal length (discussed in the next section), camera format, and how far an object is from the camera will determine how large an object is within the scene, as well as how many active picture elements the object covers on the camera imaging device. Higher resolution cameras (for example, 576 horizontal lines or higher) can be used to distinguish objects farther away (smaller in the scene) than a lower resolution camera (approximately 250 horizontal lines) allows. In other words, an object can be smaller in the scene for higher resolution cameras and still meet the minimum horizontal resolution criteria. The significance of this is that fewer higher resolution cameras will be needed than low-resolution cameras in some interior and many exterior applications.

Lenses. A camera lens focuses light reflected from objects within a scene onto the imaging device of the camera. The imaging device converts light to an electrical signal. Lens focal length and aperture are two important parameters to consider.

Lens focal length describes the relative magnification of the lens. The camera field of view (defined below) will be dependent on the lens focal length, along with the camera imager format size. Similar to the camera imager format, there is a format size for lenses. For most cases, the lens format size should be matched to the camera imager format size. Mismatched format sizes can result in the focused image being too large or too small for the camera imaging device. Different camera and lens formats can be used satisfactorily in a few instances.

Except for the most uncommon sizes, there usually is not a large price difference between various lens sizes. The most common sizes are 4.8mm, 5.6mm, 8mm, 12mm, 16mm, 25mm, and 35mm. A 35mm lens has the longest range with the narrowest field of view. The 4.8mm lens can see much shorter distances, but it will have a much wider field of view. Most lens sizes can be used in exterior applications, depending on the view desired. Shorter focal length lenses, such as 4.8mm or 5.6mm, are typical for interior applications, due to the shorter distances involved.

The important thing to consider is that the camera field of view depends on the focal length and format size. Camera field of view is expressed in horizontal and vertical angular fields of view. Most camera manufacturers or manufacturers' representatives who sell lenses with their cameras can provide charts that list the angular fields of view for common lens sizes. Exhibit 2.10 shows the difference between two different lens focal lengths.

The lens aperture, or speed of a lens, is a relative measure of the ability of the lens to gather light. Aperture is expressed as the F-number. The F-number is the ratio of lens focal length to its clear aperture. Clear aperture is the diameter of the inside of the lens where light passes through when the lens iris is fully open. A lens that is designated as an F/2 will have a clear aperture size that is one-half its focal length, meaning that a 16mm focal length lens will have a clear aperture of 8mm. The lower the F-number of a lens, the more light the lens can gather. This becomes important when operating a camera at low light levels, such as at night with artificial lighting. Most security camera lenses today have F-numbers of 1.8 to 1.4. These are usually adequate for night applications given that the minimum light levels for CCTV are provided.

Not all lenses are the same, however. Two different lenses with the same F-number can have different light-gathering capabilities. This is particularly true when it comes to fixed focal length lenses versus variable focal length (zoom) lenses. Zoom lenses have more glass elements than fixed focal length lenses. Because of the additional glass elements, an F/1.8 zoom lens will not be able to pass as much light as an F/1.8 fixed lens with fewer glass elements. An amount of light transmission is lost in each glass element. This is important to consider during night operation under artificial lighting. A zoom lens will require higher lighting levels than a fixed focal length lens if an equivalent picture quality is desired.

Most lenses for security cameras will have an adjustable iris to control the amount of light that is received at the camera imager. The iris is either manually adjustable or electronically controlled. The electronic iris (or auto-iris) monitors the camera video signal output and will open the iris for decreasing light levels and close it for increasing light levels. This keeps the video level (brightness and contrast) fairly constant under varying lighting conditions. In the case of a manual iris lens, the user or installer adjusts the iris opening for the proper video signal level for the expected operational lighting level. If light levels change, an adjustment to the iris will be required in order to maintain a proper video signal level. Manual iris lenses are used mostly in interior applications where no outside light comes in and the light levels remain constant. For all exterior and many interior applications, an auto-iris lens will be necessary.

A relatively new feature in many cameras is the electronic shutter. The electronic shutter is part of the imaging device and can perform close to the same function as an electronic iris. It controls the amount of light that the light-sensitive elements within the camera imager receives. Electronic shutters have limitations, however. They may not have as much range as auto-iris lenses. This is an important consideration for exterior applications. If light control is totally dependent on a shutter (a manual iris lens is used instead of an auto-iris) in an exterior application, the shutter may not be able to reduce light enough on bright, sunny days,

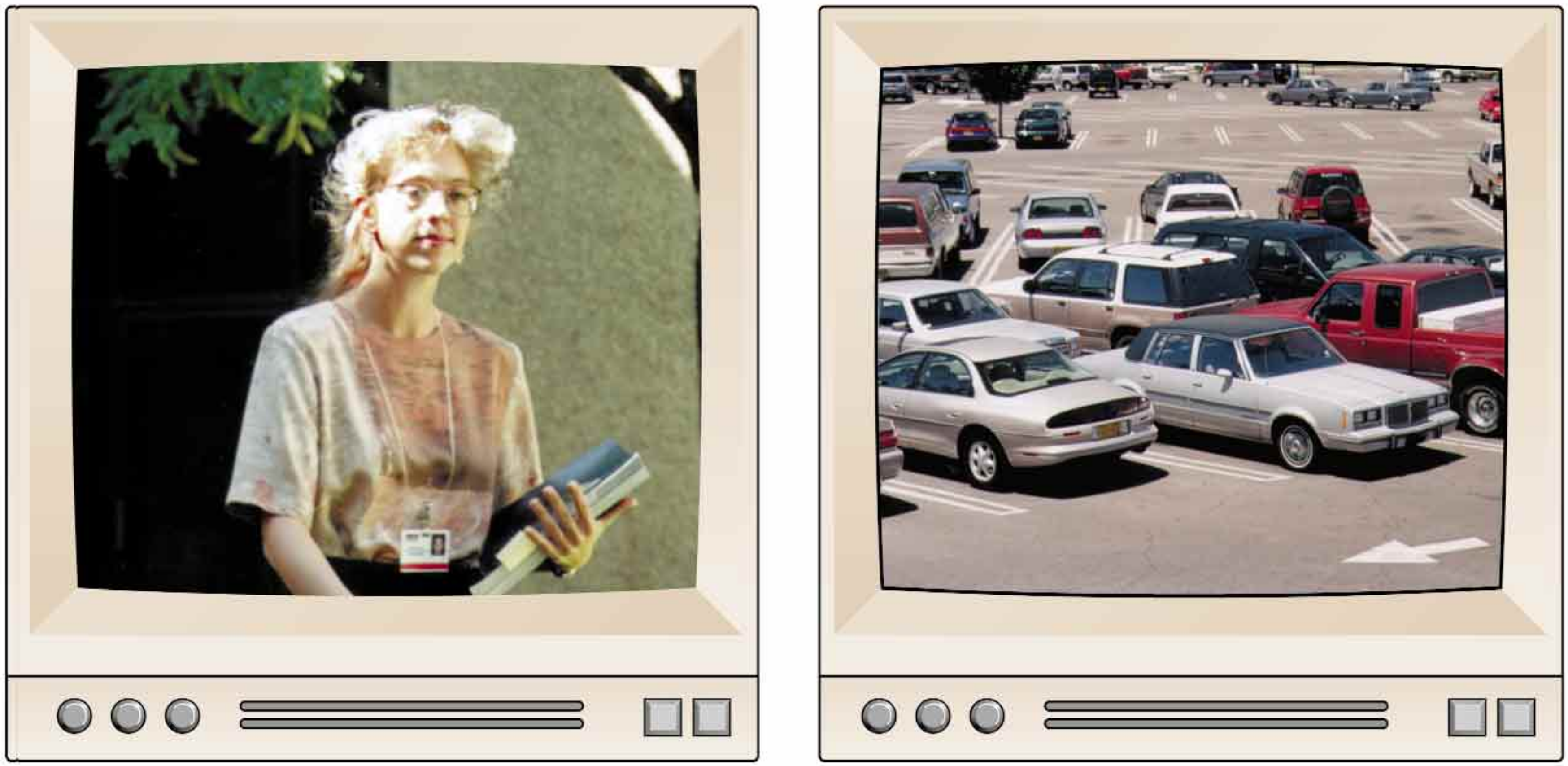

Exhibit 2.10. The left-hand image demonstrates a camera lens focal length of 4.8mm. The right-hand image uses a focal length of 16mm.

resulting in portions of the picture washing out. If the manual iris lens is partially closed to compensate for bright sunshine, low-light conditions may produce a dark, noisy picture. Many shuttered cameras intended for exterior use will also come with an auto-iris lens.

Field of view. Field of view (FOV) relates to the size of the area that a camera will see at a specific distance from the camera. The field of view is dependent on lens focal length and camera format size.

The FOV width and height can be calculated using the following formulas:

$$\text{FOV Width} = \frac{\text{Format (horizontal in mm) x Distance in feet from camera}}{\text{Focal length}}$$

$$\text{FOV Height} = 0.75 \text{ x FOV width}$$

Manipulating the FOV formula allows a calculation of the distance in feet from the camera for a required FOV width. The formula becomes:

$$\text{Distance (in feet from camera)} = \frac{\text{FOV width x Focal length}}{\text{Format (horizontal in mm)}}$$

Before the FOV for a camera is selected, the minimum desired resolution for an intruder or object to be viewed must be determined (i.e., whether it is desired to identify a person or to just determine if a person is within the scene). This will limit the maximum FOV width and is referred to as the resolution-limited FOV (exhibit 2.11). The resolution-limited FOV width can be determined by using camera resolution in horizontal lines per foot and the number of lines of resolution per foot required to identify an intruder. The following formula is used to calculate the resolution-limited FOV width:

$$\text{Resolution-limited FOV width} = \frac{\text{Camera resolution}}{\text{Number of lines of resolution}}$$

A resolution of 16 lines per foot is considered acceptable for identifying most people. If a camera with 350 horizontal lines of resolution is utilized, the resolution-limited FOV width for a resolution of 16 lines per foot can be calculated as follows:

$$\text{Resolution-limited FOV width} = \frac{350}{16} = 22'$$

The following table presents the horizontal camera format sizes of the imager for various size imagers: Example: Calculate the maximum distance from a 350-line, horizontal resolution, $^1/_2$-inch format camera with a 75mm lens to the resolution-limited FOV width at 16 lines per foot resolution.

Camera imager format size	$^1/_4$-inch	$^1/_3$-inch	$^1/_2$-inch	$^2/_3$-inch	1-inch
Horizontal format	3.0mm	4.9mm	6.4mm	8.8mm	12.8mm

$$\text{Distance} = \frac{22 \text{ x } 75}{6.4} = 258'$$

Exhibit 2.11 illustrates that there is camera coverage beyond the resolution-limited area but the resolution will decrease as the distance from the camera increases. People may be seen but not identified beyond the resolution-limited FOV area. The figure also demonstrates that, as people walk toward the camera and into the blind area, they disappear from view starting with their feet.

Another method of calculating the field of view is to use a lens selection wheel. These are mechanical computing

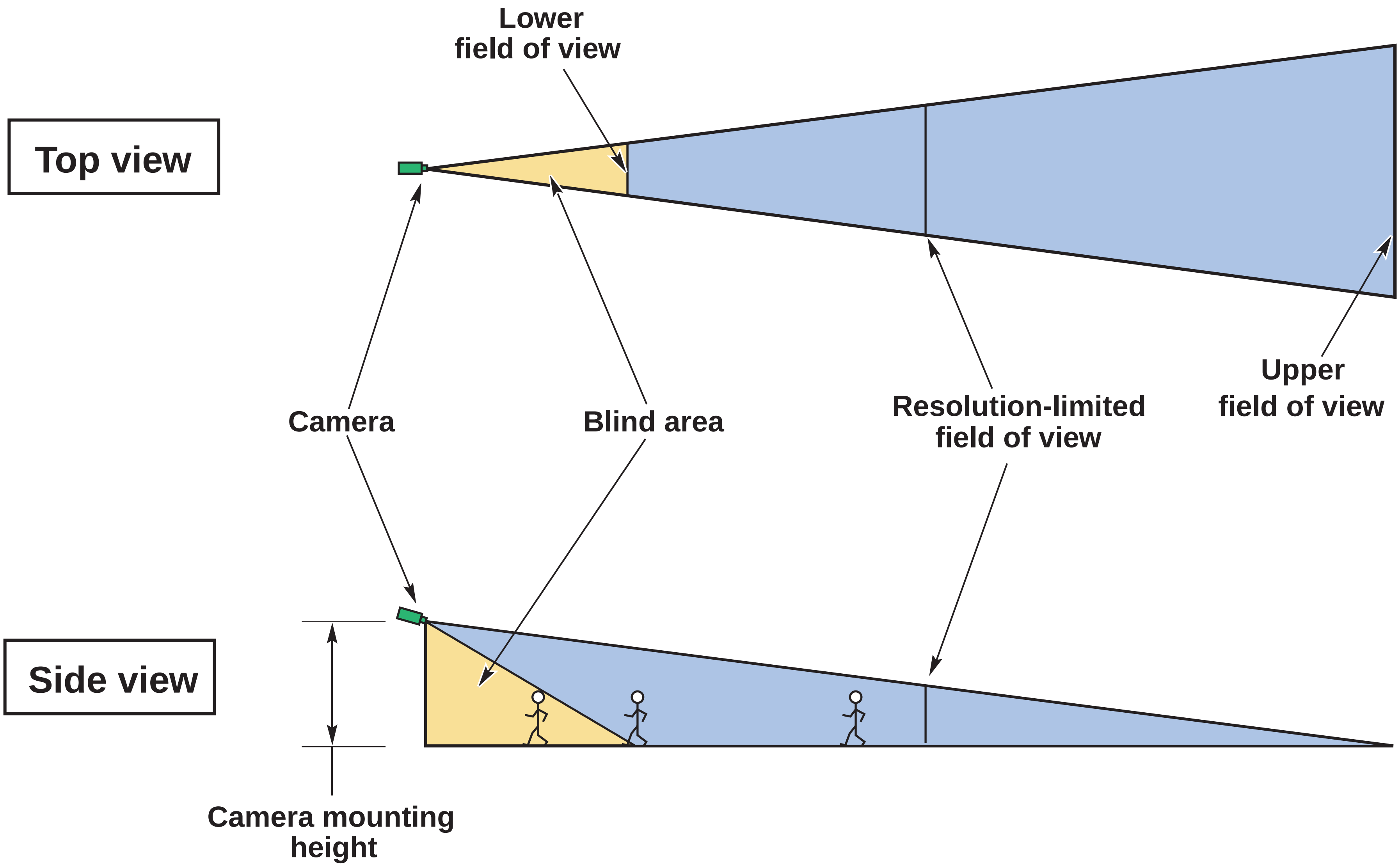

Exhibit 2.11. Field of View Camera Coverage

wheels that are available from many lens manufacturers and CCTV manufacturers. They will give a good approximation of FOV parameters.

A viewfinder can also be used to determine the field of view of a lens. This is a specially designed lens through which one can view the scene of interest. The scene is masked through the lens in such a way as to represent the picture that will be seen on the monitor. The scene desired can be dialed up on the viewfinder and the focal length of the lens required for the particular imager format size of the camera read from the side of the viewfinder. A viewfinder only determines a lens focal length value; other parameters must still be calculated.

Some lens manufacturers have developed tables for determining the field of view. The format size and focal length of the camera is cross-referenced to the column of the desired distance, and the width/height of the field of view is read from that column.

In summary, whether a camera scene is useful depends on whether objects can be distinguished in the scene. Camera resolution, camera format size, lens focal length, as well as lighting, shadowing, camera aiming, and camera sensitivity all play a role in being able to distinguish objects. Resolution and performance of other components such as TV monitors, recorders, and signal transmission equipment must be considered also. Cameras are specified with the number of horizontal lines of resolution and active picture elements. Most security cameras available today range from 300 to 700 horizontal lines of resolution. Black-and-white security cameras commonly have a horizontal resolution of 500 to 600 lines, while color cameras for security applications have 300 to 400 lines. In many exterior applications and some interior applications, a greater number of low-resolution (200–300 lines) cameras may be necessary in order to distinguish objects than would be necessary using higher resolution (500–600 lines) cameras.

9. Camera housings

One of the first considerations in selecting a camera housing is the environment. Is the camera to be installed outdoors or indoors? For indoor housings, the overall conditions where the camera is to be installed must be considered. Is the camera to be installed in a classroom, pool area, gymnasium, hallway, lobby area, or inside a school bus? A camera housing design can either help or hinder the installation and maintenance of a camera. In the outdoors, a watertight housing is desired; in some areas a heater may be required. Good ventilation is required in warmer climates. Domed enclosures are a special version of housings that can be used to conceal the position of the camera(s) via the use of viewing windows and various liners. The dome housing may also offer a more attractive look that can be designed to blend into its environment.

When installing housings in areas that drop below 30°F, the housing should have a heater. This is not so much to keep the camera warm as it is to protect the lens and to keep the viewplate free from condensation. Many auto-iris and zoom lenses can begin to experience mechanical problems at temperatures close to and below freezing. For this reason, the housing heater should be located toward the front of the housing, preferably in a U-shape or circle around the lens area. This will keep the lens warm and the front faceplate clear. The camera itself will provide ample heat (under most conditions) to keep it operational. Check the specifications listing for the camera's operating temperatures. In extremely cold environments, it may be necessary to purchase a housing that is also insulated. Extremely cold environments would be any location where temperatures drop to less than -30°F.

A sunshield may be required in some locations. A sunshield can provide artificial shade and serve as a glare screen. A sunshield can lower the internal temperature of a housing by 10–15°F and can reduce the effects of sunrise/sunset glare. Dome housings, because of their overall design, do not usually have a sunshield option.

In warmer climates, housing ventilation may be required. Many housings or domes have an optional fan attachment and air vents. Filters over the vents will need to be cleaned or replaced on a regular basis, thus adding to maintenance requirements. Sealed housings with fans for heat dissipation or condensation control can be used, but are usually more expensive.

Humidity can do the most damage to cameras and other electronic equipment. If the camera is to be installed in an obviously high-humidity area, a pressurized environmental housing may be required. These are purged and pressurized with dry nitrogen. The sealed pressurized housing ensures that changing outside pressures will not force any dirt, humidity, and/or oxygen into the tube. Cabling for these units is installed through the back via a specialized plug.

Corrosion caused by salt can be a major problem in areas of the country with high humidity that are near an ocean (such as Florida). In pool areas, chlorine is a problem. These different types of corrosives can reduce the life expectancy of a camera or lens dramatically. Therefore, if an environment is considered corrosive, only those housings or domes that are considered environmentally sealed should be used.

A camera's vulnerability to vandalism must be taken into consideration (exhibit 2.12). A housing or dome that can accommodate a lock may be required. To prevent tampering, the housing should be made of steel, although fairly tough plastic housings are available. Such tamper-proof housings or domes are often made of 10-gauge (or higher) steel.

Some situations call for bullet-resistant housings. These units are usually constructed of 12-gauge stainless steel. The front glass will be constructed of a 1/4-inch or thicker Lexan-type material. Two squares of 1/4-inch plate glass sandwiched around a 1/4-inch square of Lexan can probably prevent scratching of the surface due to washing, wind, and dust.

When choosing a proper housing or dome, it is important to consider the actual dimensions of the unit. Refer to the camera and lens specification sheets to determine the size of the housing. Leave enough room for cable connectors. The objective is to keep the unit small but allow room for everything to fit and to be accessible. Ideally, the selected housing will allow the camera to be focused and the parameters adjusted while the camera is mounted inside the housing. This depends on the design of the housing. Some housings have a hinged cover, opening from the top, that allows for easy focusing and adjustment. If mounted inside near the ceiling, this type of housing may not be feasible. Some housings allow the cover to slide off the base for easy adjustment of the camera parameters.

The prices of camera housings vary considerably. When going out on bid, be certain that your requirements document includes the features you will need.

Exhibit 2.12. A visible camera overseeing a known trouble area can quickly dissipate a crowd, but be certain that you have provided a vandal-resistant or even bullet-resistant housing for the camera.

10. Placement and mounting

To avoid the effects of blooming, streaking, and glare, all of which can wash out the video image, exterior cameras should be mounted below the nighttime lighting sources and aimed downward to shun direct sunlight, especially that occurring during sunrise and sunset. This may require a minimum mounting height of 18–20 feet. An even higher mounting height will help prevent vandalism of the camera. Consider the height required if a truck can be parked directly beneath the camera, where a perpetrator could stand on the truck's cab to reach the camera. Cameras should always be mounted on solid surfaces to prevent wind movement and vibration. Wooden poles can twist with high winds over a period of time and cause the camera view to change. Under these conditions, the camera may periodically require direction alignment.

In the interior environment, cameras cannot be mounted higher than the ceiling so it may be easier for an intruder out-of-view of the cameras to vandalize or tamper with them. This situation can be helped if the scene viewed by two cameras includes the other camera, such as cameras mounted at each end of a hallway or room and aimed to include a view of the other.

Cabling to the cameras must be protected from vandalism and tampering. In interior installations, wires can be hidden from view and therefore protected by routing them through the ceiling and/or walls. However, the small amount of wiring that may run from the camera to the wall or ceiling must be in a conduit. Also be aware that employees with access to the ceiling could tamper with your camera wiring.

For exterior camera installations, the video and power cabling to the cameras should be installed in a conduit. For underground runs, special cabling for direct burial should be used if the cable is not installed in a conduit. The cable running up poles or buildings to the cameras must be in a conduit because this is a very vulnerable location for vandalism and tampering.

Camera mounts should be selected to handle the weight of the camera, lens, and housing. A good rule of thumb is to select a mount that will handle twice the weight of the load as calculated from the specification sheets of the selected components. Mounts are usually specified as indoor or outdoor mounts. A mount designated for installation outside also can be used for interior installations, but an indoor mount should not be used outdoors. Outdoor mounts are treated for corrosive effects not normally encountered indoors (although one common exception would be in a high-humidity area such as an indoor pool). Some mounts have separate mounting bases and must be selected for either suspended ceiling or solid wall/ceiling mounting locations. Pole mount brackets are available for some outdoor camera mounts. The mounts should have adjustable heads to allow for up/down and sideways adjustment of the camera field of view. Mounts also come in different lengths, and this may be a consideration when a camera housing adds to the length requirement. Primarily, the mount should be rigid enough and mounted securely enough to the surface so that the camera does not vibrate under normal operating conditions.

Many camera manufacturers and distributors also carry a full line of camera mounts, as well as housings for their cameras. Mounts are priced anywhere from approximately $30 to $150.

11. Lighting requirements and nighttime applications
Most schools generally will not attempt to use exterior CCTV cameras during the nighttime because of the high light levels that are required.

For exterior nighttime CCTV applications, proper lighting is very important. A number of lighting types are available. These types include incandescent, fluorescent, and high-intensity discharge. Incandescent lighting is the most expensive to operate and includes the flood or quartz lights that are commonly used for exterior home security applications. Most fluorescent lighting is used indoors for office and work area lighting. High-intensity discharge lighting is the least expensive to operate (more light is produced with less power consumption) and is the most common for commercial exterior lighting applications. It includes high-pressure sodium and low-pressure sodium lighting. A disadvantage of high-intensity discharge lighting is the restrike time. If a momentary power outage occurs, these lights will go out and can take up to several minutes to return to full brightness. The advantages of high- and low-pressure sodium lighting, however, outweigh this disadvantage for CCTV applications.

Low-pressure sodium lighting is the most desirable choice for exterior CCTV applications because it is somewhat more efficient to operate than high-pressure sodium, and the types of light fixtures available provide a fairly uniform light pattern. A disadvantage to low-pressure sodium is the monochromatic yellow light it produces, which some people find objectionable.

Important items to consider for nighttime camera lighting are illumination level, camera sensitivity, lens type, light-to-dark ratio, area of illumination in the camera field of view, and lighting position. Note: These are not simple issues to be addressed by a neophyte. Be certain that you discuss lighting issues with your local power company or lighting expert.

Illumination level, camera sensitivity, and lens type. Lighting levels must be high enough for the camera to produce a useable image. The light level required will depend on camera sensitivity and lens type and quality. Black-and-white cameras generally have more light sensitivity than color cameras and are recommended for most nighttime applications. A minimum illumination level of 1.5 foot-candles, as measured on a horizontal plane 1 foot off the ground, is recommended for a black-and-white camera with a sensitivity specification of 0.007 foot-candles faceplate illumination. This assumes the camera has a good-quality, F/1.4 fixed focal lens. A color camera or a camera with a zoom lens will require a higher light level in order to get equivalent brightness and contrast.

Light-to-dark ratio. A recommended maximum light-to-dark lighting ratio is 6 to 1 (as measured on a horizontal plane 1 foot off the ground). This maximum applies to the entire area of interest that the camera is viewing. It is also recommended to design the lighting for a 4-to-1 ratio to allow for some degradation over time. A 6-to-1 light-to-dark ratio will prevent areas that are so dark or so bright that a person or object would be obscured.

Area of illumination in the camera field of view. A minimum illumination of 70 percent of the camera field of view is recommended. A camera is an averaging device. If too little of the field of view is illuminated, the camera will average between the illuminated areas and the nonilluminated areas, resulting in blooming and loss of picture detail in the illuminated area.

Lighting position. The position of lighting in relation to the camera field of view is also important. As much as possible, light sources must be kept out of the camera's field of view. Lights that are illuminating a camera scene should be mounted higher than the cameras. When determining a location and field of view for a camera, extraneous light sources, such as building-mounted lighting for pedestrians that will be in the camera view, must be considered. Extraneous light sources can cause blooming and streaking in a camera, rendering portions of the field of view unusable. Distant light sources that are relatively dim are usually not a problem.

Other lighting. Another type of lighting is known as infrared (IR) or near infrared. The spectrum for this lighting is just below red and is not visible to the human eye. Most black-and-white cameras have sensitivity into the infrared. A black-and-white camera can be used with this type of lighting to observe areas at night without having lighting that is visible to humans. To make use of IR lighting, the camera must not have an IR cut filter. Cameras can be ordered without IR cut filters; be sure to specify no IR cut filter when ordering.

Commercial IR light sources include incandescent and the light emitting diode (LED). The incandescent type typically use a 300- to 500-watt lamp and a visible light cut filter. These are expensive to purchase ($800–$1,200) and expensive to operate and maintain (2,000 hours is a nominal life expectancy of the incandescent lamp). The LED type emits light in the IR and is also expensive to purchase (around $1,200) but uses less power and has a much longer life expectancy. The incandescent type will provide more illumination than the LED type. With either type of IR light, more light fixtures will be required to illuminate an area than with visible lighting. While IR lighting has the advantage of not being visible to humans, it is fairly expensive.

Alternatives to lighting. There are two camera technologies that can see at night without the use of artificial lighting. These technologies are intensified cameras and thermal cameras, though they are probably both cost-prohibitive for most schools. Intensified cameras use a photomultiplier (light intensifying) tube in front of the camera imaging device. Depending on the generation of the photomultiplier tube, these cameras can produce a picture in conditions ranging from moonlight to starlight. Disadvantages of these cameras include initial costs, maintenance costs, and lower resolution. Costs for an intensified camera can begin around $8,000. The photomultiplier tube has a life expectancy in the range of 8,000 to 10,000 hours, requiring replacement every 1–2 years depending on the amount of use. In terms of horizontal TV lines, intensified cameras have lower resolution than a good-quality surveillance camera.

Thermal cameras are sensitive to thermal energy radiated by objects. The low-end and minimum-performance thermal cameras start around $7,000. The high-performing thermal cameras range up to $30,000 and require equipment for cooling the thermal imaging device. This cooling equipment can be maintenance intensive. Resolution is also lower than in general CCTV surveillance cameras. Uncooled cameras are currently coming down in price and may offer a better alternative in the future.

12. Covert cameras

There may be times when it is suspected or known that unlawful events, including drug deals, fighting or intimidation, vandalism, or nighttime theft, are occurring on campus. With cameras in plain view, it is clear to all where not to carry out such dealings but; where incidents of concern are out of sight, it may be beneficial to temporarily install a camera hidden from view of the suspects (exhibit 2.13). (Schools should make certain that they consult an attorney before utilizing hidden cameras.)

Cameras hidden from the view of suspects under investigation are referred to as covert cameras. In school applications, these cameras are generally hidden behind a wall or ceiling or within a common building fixture. In some instances, it may be practical to use a normal size, readily available camera if a convenient hidden location is available, such as behind an air duct. It would be reasonable for a school district to have at least one smaller camera available for covert applications.

A whole new industry has arisen in the past few years that specializes in these tiny, easily hidden cameras. These tiny cameras designed for hidden applications are available in black-and-white or color. Microphones are included with some cameras, but caution is advised in their use due to state laws regarding privacy of conversations. An amazing array of disguised cameras already installed within smoke detectors, clocks, speakers, light switches, junction boxes, neckties, caps, and so forth are available in security trade journals; it is then up to the security department to appropriately place the item where it will not be suspicious. The size of available covert cameras themselves measure about 1.25 inches square. The lenses, including pinhole lenses, come in sizes ranging from 2.5mm to 25mm. Covert kits will provide both the camera and a set of several lenses that will handle a wide range of applications, from wide-angle to telephoto. Passive infrared cameras and surface-mount cameras also are available. They can allow surveillance in some low-light environments. Voltage requirements for the cameras are normally 9 or 12 volts dc and can be battery powered.

The video recorder that will be necessary to record the images captured by a covert camera must also be hidden from view. This may not be a simple matter. The smallest video recorder is much larger than the smallest camera. It requires ventilation, a somewhat clean environment, accessibility, and it makes noise. It may be necessary to install the recorder in a separate secure room or even in another building.

The video signal must be transmitted from the camera to the recorder. Coaxial cable is needed for these connections. Wireless covert board cameras are available. Although their use can greatly simplify installation, their transmission ranges are limited to about 300 feet.

Covert black-and-white board cameras start at around $150, with a resolution of about 380 lines. Color covert cameras are close to $300, with a resolution of around 330 lines. For these operations, black-and-white cameras may be adequate or even desired. Many covert situations occur in fairly small areas, and a higher resolution black-and-white camera may be more appropriate than a lower resolution color camera. Cameras already mounted covertly within a fixture can cost between $250 and $500. Wireless cameras can range from $500 to $1,000 or more.

Exhibit 2.13. This shows the relative size of a typical covert camera.